Proton-proton final state interaction

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One of the aim of the COSY - 11 collaboration is the investigation of the $pp \to ppMeson$ reactions. By measuring the four momenta of the two outgoing protons one can identify the produced meson via the missing mass method. In order to determine the total reaction cross section one needs to know both the geometrical acceptance of the detection system and the angular distribution of the reaction products. The latter one can be strongly influenced by the final state interaction between outgoing particles.

The momentum distribution of the outgoing protons is governed by the three body phase space and the reaction matrix element. Following the Watson procedure one can separate the energy dependence due to the final-state interaction between the outgoing protons from the reaction amplitude. If we assume that for the reactions at threshold the reaction amplitude is constant and that the Meson-proton interaction is negligible, we can generate the momentum distribution of the outgoing protons taking into account only kinematical factors and the proton-proton final state interaction. The Watson method is valid if the relative momenta between the interacting particles are small, and the final state interaction is strong compared with the primary reaction[1].

The proton-proton scattering amplitude for the relative angular momentum l=0 is expressed by [2]:

$$A_{pp} = \frac{e^{i\delta_{pp}} \cdot sin\delta_{pp}}{C^2 \cdot q}$$

In this equation q denotes a momentum of either proton in the proton-proton center of mass system. The Coulomb penetration factor C^2 in the denominator is due to the Coulomb interaction between two protons. The phase shift δ_{pp} is obtained from the modified Cini-Fubini-Stanghellini formula:

$$C^2 qctg^2\delta_{pp} + 2q\eta h(\eta) = -\frac{1}{a_{pp}} + \frac{1}{2} b_{pp} q^2 - \frac{c \cdot q^4}{1 + dq^2}$$

where η (relativistic Coulomb parameter) and $h(\eta)$ are defined in a reference [3], a_{pp} and b_{pp} denote the scattering length and the effective range respectively. The parameters c and d are not phenomenological constants, but are computed from the pion-nucleon coupling constant and the pion mass according to formulas from a reference [4].

Figure 1 shows distribution of the relative momentum of the outgoing protons, calculated for the $pp \to pp\eta\prime$ reaction for a beam momentum 15 MeV/c above threshold, a) according to the phase space without proton-proton FSI - solid line, and b) with proton proton FSI dashed line.

As an example, in figure 2 the COSY - 11 detection system efficiency is shown of the $pp \to pp\eta\prime$ reaction calculated with the point-like target and beam momentum without spread. Already at a beam momentum of 10 MeV/c above threshold for instance, calculations of the efficiency performed with and without proton-proton FSI differ by about 10% .

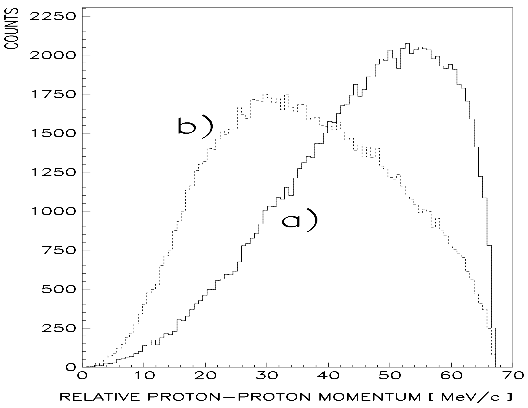

Figure 1: Relative proton-proton momentum distribution for the $pp \to pp\eta\prime$ reaction without proton-proton FSI - solid line (a), and with proton-proton FSI - dashed line (b).

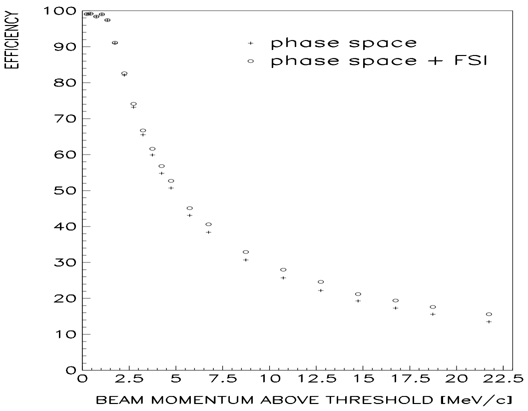

Figure 2: Efficiency of the COSY-11 detection system for the $pp \to pp\eta\prime$ reaction

References

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